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*SECTION OF BIOLOGY**

THE PRACTICAL THEORY OF PHASE MICROSCOPY†

By HAROLD OSTERBERG‡

Introduction. Although the elementary theory of phase microscopy is admittedly oversimplified, it will comprise for some time the most understandable and practical theory for interpreting qualitative and quantitative observations with the phase microscope. The brightnesses predicted by the elementary theory behave as a step-function that rises or falls abruptly at the edge of the geometrical image of the particle from a value G_s, in the image of the surround, to a value G_p over the image of the particle (FIGURE 1).

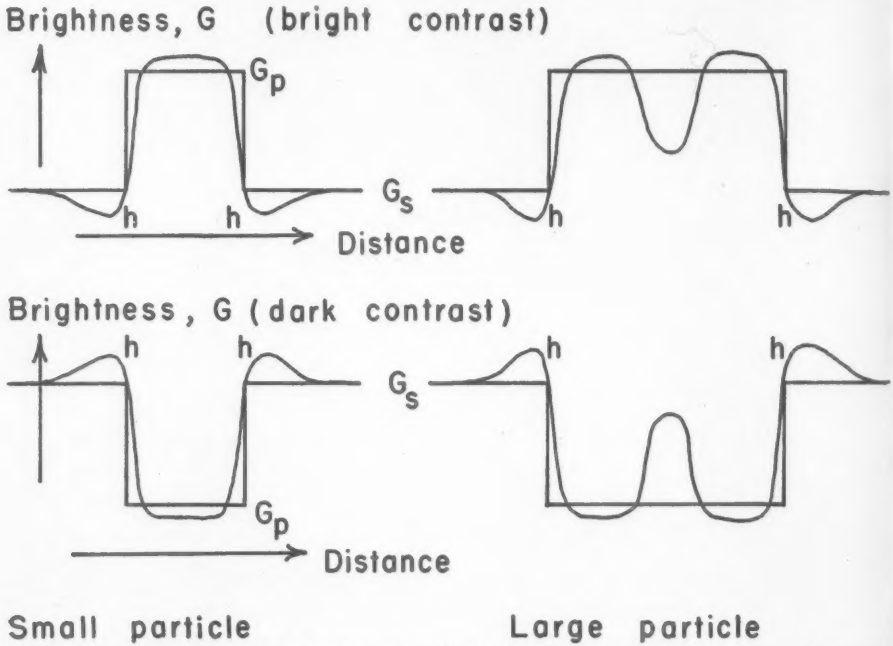

FIGURE 1. Qualitative comparison of the theoretical and actual brightnesses (G) in the image plane. G_p and G_s are the theoretical brightnesses in the image of the particle and surround, respectively. The halo (h) appears around the actual image of the particle.

In a phase microscope (FIGURE 2), the plane of the condenser diaphragm, (D) is focussed by the intervening lenses of the substage condenser and the objective upon the plane of the diffraction plate (P). The opening in the condenser diaphragm is usually (although not necessarily) annular. The portion of the diffraction plate which coincides with the image of the opening in the condenser diaphragm is called the conjugate area. The remaining effective area of the diffraction plate is called the complementary area.

The undeviated rays obey the laws of geometrical optics, and they are represented by the solid lines of FIGURE 2. The undeviated rays originating at S are focussed upon point S' in the conjugate area and subsequently are spread out over the image plane. The deviated rays originate by diffraction at the object. They are represented by

* The Section of Geology and Mineralogy held a meeting on February 4 at which a paper entitled "East African Geologic Structures" was read by M. Hall Taylor. The Section of Physics and Chemistry held a meeting on February 5 at which a paper entitled "Some Fundamental Aspects of Ion Exchange Resin Systems" was delivered by Harry P. Gregor. No abstracts of these papers have been received.

† This paper was presented as part of the Symposium on Phase Microscopy at the meeting of the Section, February 11, 1952.

‡ Research Laboratory, American Optical Company, Stamford, Connecticut.

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the broken lines. These rays diverge from the particle O, spread over the diffraction plate and come to focus over the image O' of the particle. If the conjugate area is negligibly small compared to the complementary area, practically all of the deviated rays pass through the complementary area.

By coating the conjugate and complementary areas differently with absorbing and refracting materials, it is possible (in the manner of Zernike) both to alter the amplitude ratio (*i.e.*, relative strength) of the undeviated and deviated waves, and to introduce phase differences between them.

amplitude of the wave is reduced by passage through the medium in proportion to the amplitude transmittance of the medium. The square of the amplitude transmission is the usual energy transmittance (formerly called transmission).

We shall use the symbol $|V|$ to denote the length of any vector V, and hence to denote its amplitude.

The P and S-Waves. For the sake of simplicity of argument, it is supposed that the opening in the condenser diaphragm is a pinhole on the optical axis. The rays now emerge from the condenser substantially parallel to the optical axis (FIGURE 4),

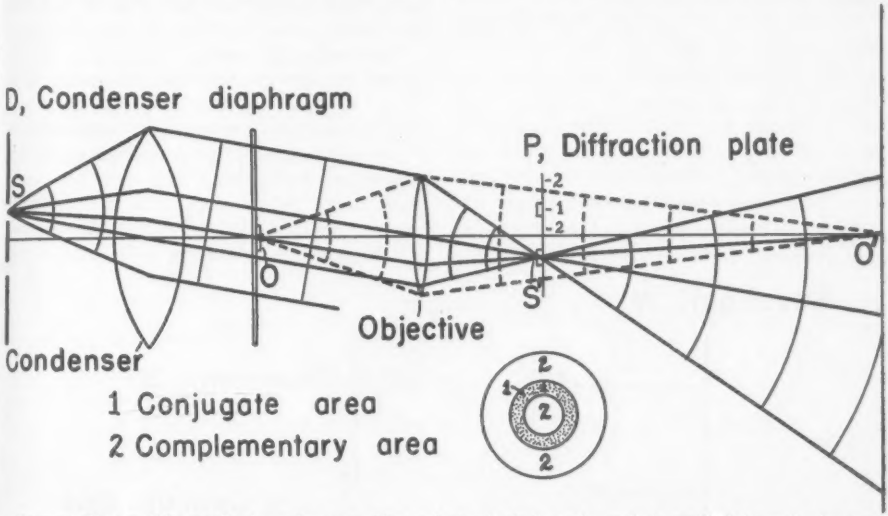

FIGURE 2. The essential parts of a phase microscope. The annular opening in the condenser diaphragm (D) is focussed and centered upon the conjugate area 1 of the diffraction plate (P). Contrast in the image O' of the object (O) can be modified favorably by coating the conjugate and complementary areas with refracting and absorbing materials.

This can be accomplished because the undeviated and deviated rays (and hence waves) are separated at the conjugate and complementary areas. Consequently, as one wishes the particle to appear brighter or darker than its surround, the undeviated and deviated waves may be caused, accordingly, to interfere constructively or destructively.

Vectorial Representation. The amplitude and phase of light waves are represented (FIGURE 3) by the length of the vector V and its phase angle θ. The phase angle θ is positive in the counterclockwise direction of rotation from the direction of reference v. Increasing θ corresponds to increasing the optical path (*i.e.*, product of refractive index and thickness) traversed by the light wave. The

and the wave fronts are perpendicular to the rays. A portion of the incident wavefront passes through the surround (S): let this portion be called the S-wave. The remaining portion of the incident wavefront is intercepted by the particle P and is called the P-wave.

When the optical path of the particle exceeds that of the surround, Δ, which denotes the optical path difference between particle and surround, is considered positive and drawn counterclockwise. It follows directly from the meaning of the P and S-waves that their optical path (phase) difference is Δ.

In representing the P and S-waves vectorially, we shall choose the vertical direction as the direction of reference from which to measure the phase

angles Δ. We regard the phase angle of the *S*-wave as zero. Then, if the optical path or phase of the *P*-wave exceeds that of the *S*-wave by the amount Δ, the *P*-vector appears rotated in the counterclockwise direction with respect to the *S*-wave (FIGURE 5A).

The U and D-Waves. It is always possible to replace the *P*-vector as demonstrated in FIGURE 5B, by two vectors, *U* and *D*, so that

$$P = U + D \tag{2}$$

and

$$U \equiv S. \tag{3}$$

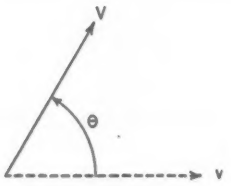

FIGURE 3. Vectorial representation of amplitude and of phase a wave as the length, $|V|$, and the angle Θ of rotation, respectively, of the vector V. The direction of reference is v.

the particle, spreads over the complementary area and comes to focus upon the image of the particle. The *D*-wave vanishes, as it should, when $P = S = U$, *i.e.*, when the particle is indistinguishable from its surround.

Bright Field Microscopy. The classical, bright field microscope transports the *U* and *D*-waves, without further relative changes of phase or of amplitude, to the sharply-focussed image plane. We have seen how the undeviated wave illuminates the image of the surround and how the undeviated and deviated waves overlap to illuminate the image of the particle. Upon arrival in the image plane, the *U* and *D*-waves thus combine to create the vectors S' and P' (FIGURE 6) over the images of the surround and particle, respectively. If the particle and surround transmit light equally, then $|P| = |S|$ and $|P'| = |S'|$. Hence, the image plane is illuminated evenly and the particle should be invisible in the sharply-focussed image plane irrespective of the optical path difference Δ between particle and surround. It is, of course, well-known that such particles are visible, provided that Δ is large enough. Visibility occurs in an automatically selected out-of-focus image plane and is, fortunately, improved by the failure of the objective to transmit the entire *U* and *D*-waves to the image plane. Closing down the condenser diaphragm improves contrast by even further restricting the amount of deviated light that succeeds in reaching the selected image plane.

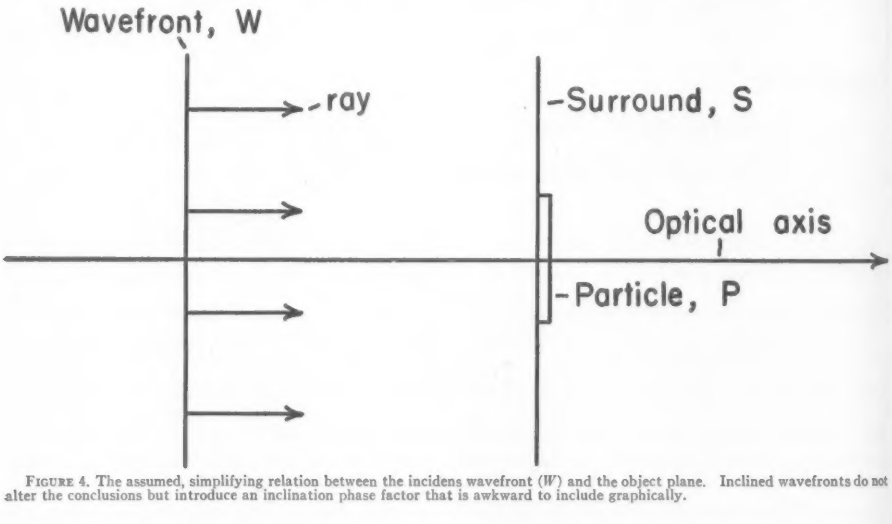

FIGURE 4. The assumed, simplifying relation between the incidens wavefront (*W*) and the object plane. Inclined wavefronts do not alter the conclusions but introduce an inclination phase factor that is awkward to include graphically.

This is an exceedingly important stride. The waves *P* and *S* can be replaced at will by the alternate pair of waves *U* and *D*. The *U*-wave is, in fact, the undeviated wave. It extends over the entire object plane, passes through the conjugate area, and then spreads over the image plane. The *D*-wave is the deviated wave. It originates at

Phase Microscopy with $\Delta > 0$. Biological particles usually exceed their surround in optical path so that $\Delta > 0$. Correspondingly, the phase angle is drawn counterclockwise in FIGURES 5A and B. Furthermore, unstained biological particles usually transmit practically the same amount of light as their surround. Consequently, the S and P-vectors are drawn the same length ($|S| = |P|$) in FIGURES 5A and B.

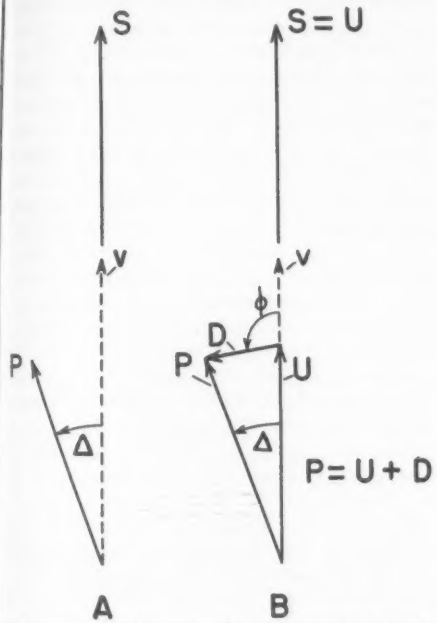

FIGURE 5. Vectorial representation and construction of the relative amplitude and phase of the four waves P, S, U and D. P and S-waves having the phase difference Δ and approximately equal amplitudes are constructed in A. The corresponding U and D-waves are constructed in B from the given vectorial values P and S constructed in A.

The constructed D-vector (FIGURE 5B) almost makes a $+90°$ angle with the vertical direction of reference. Hence, when the optical path difference Δ is small, and greater than zero, the deviated wave exceeds the undeviated wave in phase by almost 90°, *i.e.*, by almost $\lambda/4$.

Let the vector U be rotated slightly more than 90° in a counterclockwise direction. This can be accomplished, among other ways, by depositing enough refracting material upon the conjugate area to increase the optical path of the conjugate area by one quarter of a wavelength with respect to that of the complementary area. The U and D vectors now arrive in phase in the sharply focussed image plane and add (*i.e.*, interfere) constructively to produce a vector P' so that $|P'| > |S'|$ (FIGURE 7A). Accordingly, the particle appears brighter than its surround.

On the other hand, let the D-vector be rotated almost 90° in a clockwise direction (FIGURE 7B). This is accomplished by depositing refracting material upon the complementary area so as to increase its optical path by approximately one-quarter of a wavelength with respect to that of the conjugate area. The U and D vectors now arrive out of phase (*i.e.*, point oppositely) and interfere destructively to produce a vector P' so that $|P'| < |S'|$. Accordingly, the particle appears darker than its surround.

The undeviated wave (U) is ordinarily greater in amplitude than the deviated wave (D). It was soon realized by F. Zernike and others that the vector P' of FIGURE 7B can be reduced to zero, and the image of the particle made black, by adding enough absorbing material to the conjugate area to reduce the amplitude $|U|$ of the U-wave to the point $|U| = |D|$. Destructive interference between the U and D-waves is then complete.

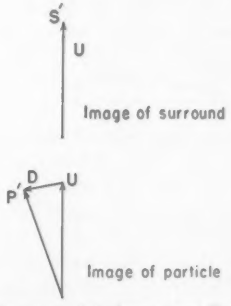

FIGURE 6. Formation of the image waves P and S' over the image of the particle and surround, respectively, by the U and D-waves upon their arrival in the sharply focussed image plane of a bright field microscope.

Phase Microscopy with $\Delta < 0$. If the optical path of the particle is less than that of an equal thickness of the surround by a small amount Δ, the phase angle Δ will be drawn clockwise instead of counterclockwise in FIGURE 5A. The D-vector will point oppositely from its direction in FIGURE 5B. The phase angle becomes almost $-90°$; meaning that the phase of the deviated wave is less, by approximately $\lambda/4$, than the phase of the undeviated wave. These two phases can be equalized by increasing the optical path of the

complementary area by approximately $\lambda/4$ with respect to the optical path of the conjugate area. The *U* and *D*-vectors are then in phase, point in the same direction, and interfere constructively to make the particle appear brighter than its surround. On the other hand, if the optical path of the conjugate area is increased by $\lambda/4$ with respect

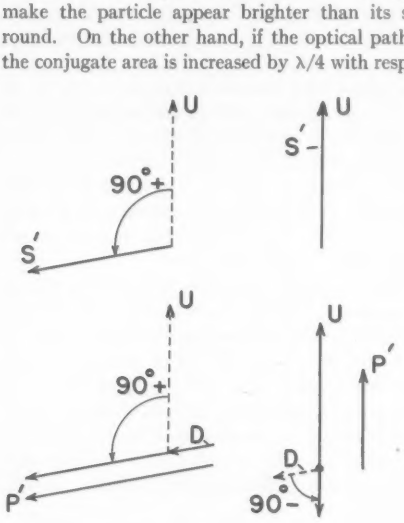

FIGURE 7. Rotation of the *U* or *D* vector to produce bright or dark contrast in the phase microscope. In *A*, the vector *U* is rotated into parallelism with *D*. Then $P' = U + D$ such that $|P'| > |S'|$. The particle appears bright. In *B*, the vector *D* is rotated into antiparallelism with *U*. Then $P' = U + D$ such that $|P'| < |S'|$. The particle appears dark.

to that of the complementary area, the phase of the deviated wave becomes less than that of the undeviated wave by approximately $\lambda/2$. The *U* and *D*-vectors then point oppositely and the *U* and *D*-waves interfere destructively to make the particle appear darker than its surround. Again, destructive interference is complete and the image of the particle is black provided that enough absorbing material is added to the conjugate area to equalize the amplitudes of the undeviated and deviated waves.

In summary, the particle is made to appear brighter or darker than its surround as a result of causing the undeviated and deviated waves to interfere constructively or destructively. This is achieved by coating the conjugate and complementary areas of the diffraction plate suitably with refracting and absorbing materials. In the cases discussed above and in the majority of practical cases, the undeviated wave has greater amplitude than the deviated wave. Darkest contrast is therefore obtained with most biological particles by reducing the light transmission of the conjugate area. The corresponding diffraction plates are called the *A*-type.

An *A*-type diffraction plate is further designated by $A + \lambda/4$ or $A - \lambda/4$ if the optical path of its conjugate area is accordingly greater or less than that of its complementary area by the amount $\lambda/4$. As a first theorem, we have unstained biological particles whose optical path exceeds that of the surround by a small fraction of a wavelength, appear brighter or darker than their surround with $A + \lambda/4$ or with $A - \lambda/4$ diffraction plates, respectively. The second theorem is: unstained particles having a slightly lower optical path than their surround appear brighter or darker than the surround with $A - \lambda/4$ or with $A + \lambda/4$ diffraction plates, respectively. The converse of these theorems is true also. If, for example, a particle appears brighter or darker than the surround with an $A + \lambda/4$ or with an $A - \lambda/4$ diffraction plate, respectively, and if the particle is known to have slight optical path difference with respect to its surround, then the refractive index of the particle exceeds that of the surround.

The interpretation of microscopic observations upon other classes of particles is more easily continued in terms of the algebraic treatment and statement[1] of the variegated laws of the elementary, practical theory of phase microscopy.

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(1) BENNETT, A. H., H. JUPNIK, H. OSTERBERG & O. W. RICHARDS. 1951. Phase Microscopy. John Wiley & Sons, New York. Pp. 48–56.

APPLICATIONS OF PHASE MICROSCOPY IN CYTOLOGY AND ELECTRON MICROGRAPHY*

By LEONARD ORNSTEIN AND ARTHUR W. POLLISTER†

Doctor Osterberg explained in the preceding paper that phase contrast demonstrates differences in optical path (*i.e.*, the thickness of an object times its effective refractive index) as different levels of brightness in the image plane of the microscope.

An oil immersion objective has a depth of focus of a little less than one micron. The in-focus layer

* This paper, illustrated with lantern slides, was presented as part of the Symposium on Phase Microscopy at the meeting of the Section of Biology on February 11, 1952.

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of object material plays the main role in influencing the rays of light which form the image. Inhomogenous material above or below this layer tends to degrade resolution and contrast by deviating the illuminating and imaging bundles of light rays from the paths which they should follow if a "perfect" image formation is to be achieved.

In the ordinary light microscope, all paths from the object through the objective lens are approximately equivalent, and deviation of the illuminating pencils ordinarily has but a negligible effect. As Doctor Osterberg indicated clearly, this is definitely not true of the phase microscope. Except for the deviation introduced by the object in the in-focus layer, all rays passing through the annular substage diaphragm must also pass through the conjugate annulus in the phase plate of the objective. The phase contrast microscope is therefore much more sensitive to the effect of out-of-focus parts of the specimen. Hence, for maximum resolution and useful contrast, very thin specimens (about one micron thick) should be used.

There is likewise an optimum range of path differences which will yield a maximum in useful contrast. This optimum is conditioned by the characteristics of the phase plate used; and for the usual medium dark contrast instrument (0.14A – 0.25λ), when used for the study of non-absorbing specimens (*i.e.*, completely transparent), this optimum range is about $\frac{1}{18}$ of the wavelength of the light used for illumination.[1] The objects of greatest optical path then appear darkest. It has been found empirically that if 1 micron sections of tissues are mounted in a medium of refractive index equal to 1.460, the maximum in resolution and useful contrast is achieved. These preparations must approach conformation to the requirement of about $\frac{1}{18}$ wavelength maximum path difference.*

At about the time we were becoming aware of the advantages of applying phase microscopy to some special cytological problems, we were making rapid progress on methods aimed at obtaining well-fixed tissue sections of one-tenth micron thickness for electron microscopy. This turned out to be a very fortunate coincidence.

* This may seem surprising, since the refractive indices of most components of fixed tissue fall between 1.53 and 1.56, depending upon the method of fixation (easily demonstrated by matching the index with a set of immersion oils under dark field or phase contrast). It would seem that in a medium of index 1.46, the path differences in one micron sections should be considerably greater than 1/18th λ. Actually, if the submicroscopic components of a cell structure have a refractive index of about 1.56, the entire structure will have an "effective refractive index" somewhere between 1.56 and that of the medium in which it is immersed, (depending in a simple manner upon the concentrations of the tissue and medium in the medium-permeated structure, and the specific refractivities of the tissue and the medium).

The unexceptionable criterion of "good fixation" is that the fixed structures should closely resemble the living in microscopic appearance. From many studies of living cells in the intact animal, in tissue cultures, *etc.*, the following characteristics of the well-fixed cell have been obvious for a long time: (1) The adequately preserved animal cell will contain no "empty areas" in the cytoplasm or nucleus (these result from differential shrinkage and/or loss of material); (2) the nucleus will contain nearly spherical nucleoli and a few conspicuous irregular masses ("heterochromatin"); (3) the mitochondria will appear as unbranched rodlets of fairly uniform diameter and length; (4) fat droplets, secretory granules, *etc.* will tend to appear as spheres with perfectly smooth surfaces; and (5) the material surrounding these cell structures will appear quite clear and structureless under the light microscope (in allusion to which it has often been called "hyaloplasm"). In short, there is a neatness and orderliness about the living cell, and long, and often sad, experience has made cytologists look with suspicion upon such disorderly structural details as intracellular clots, fibrous masses, crenated spheres, unevenly beaded rods or rows of granules, and irregularly granulated areas. These are likely to be artifacts brought about by faulty fixation. In practice, however, cytologists have rarely been able to make their painstakingly detailed studies upon perfectly fixed cells, though a sort of fixation that results in cells which look very much like living ones is often approached in one or two outer layers of cells of material fixed in non-acid fluids (*e.g.*, those devised by Benda and Champy). Until the advent of the phase microscope, cytologists were forced to rely upon artificial contrast (introduced by chemical tests, stains, or metallic impregnation) if they were to have slides on which structures stood out distinctly enough at high magnification and high numerical aperture. And the tantalizing situation has been that those best-fixed outer cells were most refractory to introduction of artificial contrast. This is notably true of the sections prepared by the double fixation illustrated in FIGURES 1–8; they cannot be selectively well stained or impregnated, although some tests, such as Feulgen's nucleal reaction, do succeed.

Phase and electron microscope study of the one micron and one-tenth micron sections made it clear that material prepared even by the very best standard cytological fixation was far from adequate. The disorderly clotted fibrous masses in

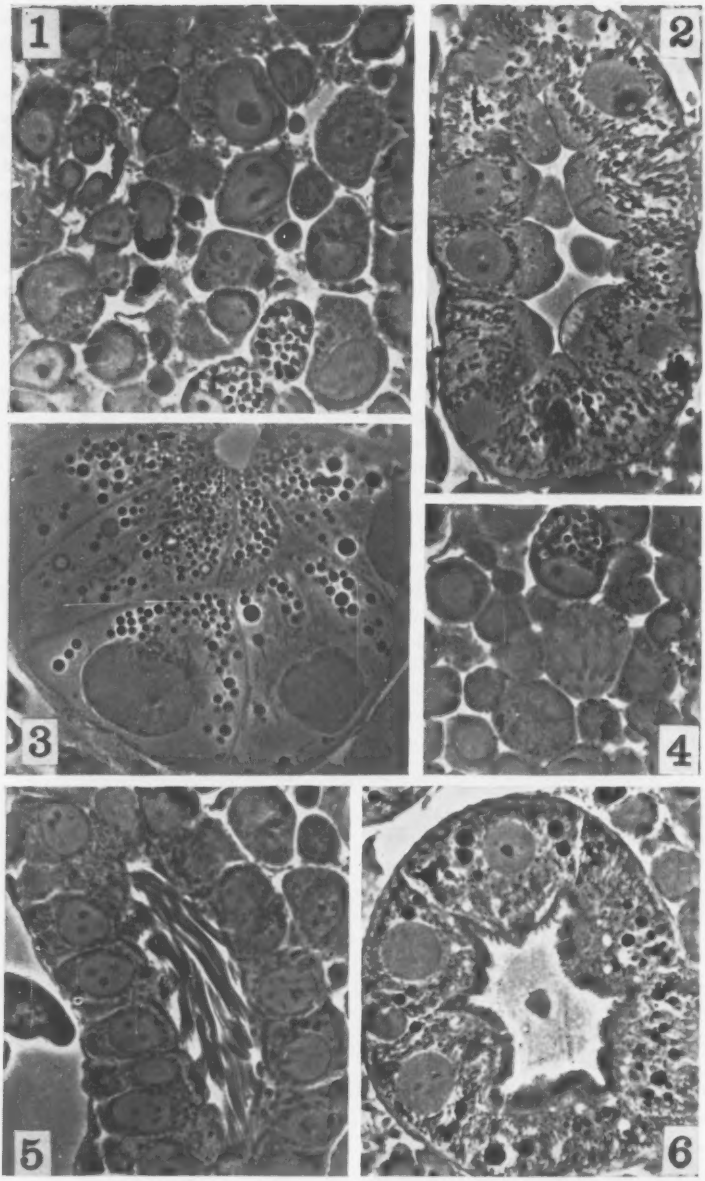

FIGURE 1.* Leucopoietic tissue from the kidney, *Rana clamitans* tadpole. Note large mitochondria of the lymphoblast just right of center of the field and the two eosinophilic leucocytes near the lower margin.

FIGURE 2. Distal tubule of the kidney, *Rana clamitans* tadpole

FIGURE 3. Pancreas of *Necturus maculosus*. Note aggregation of fine mitochondria near the "Golgi Zone."

FIGURE 4. Like Figure 1. One cell in anaphase. This is very similar to the appearance of a living cell in mitosis.

FIGURE 5. First section of the proximal tubule of the kidney, *Rana clamitans* tadpole. Note tufts of long cilia and minute mitochondria.

FIGURE 6. Main section of proximal tubule of kidney, *Rana clamitans* tadpole. Note brush border, numerous fine mitochondria, and large cytoplasmic granules.

* All figures are from material prepared as described in the text. All are phase contrast photomicrographs, from sections one micron thick, magnified 1,200 diameters.

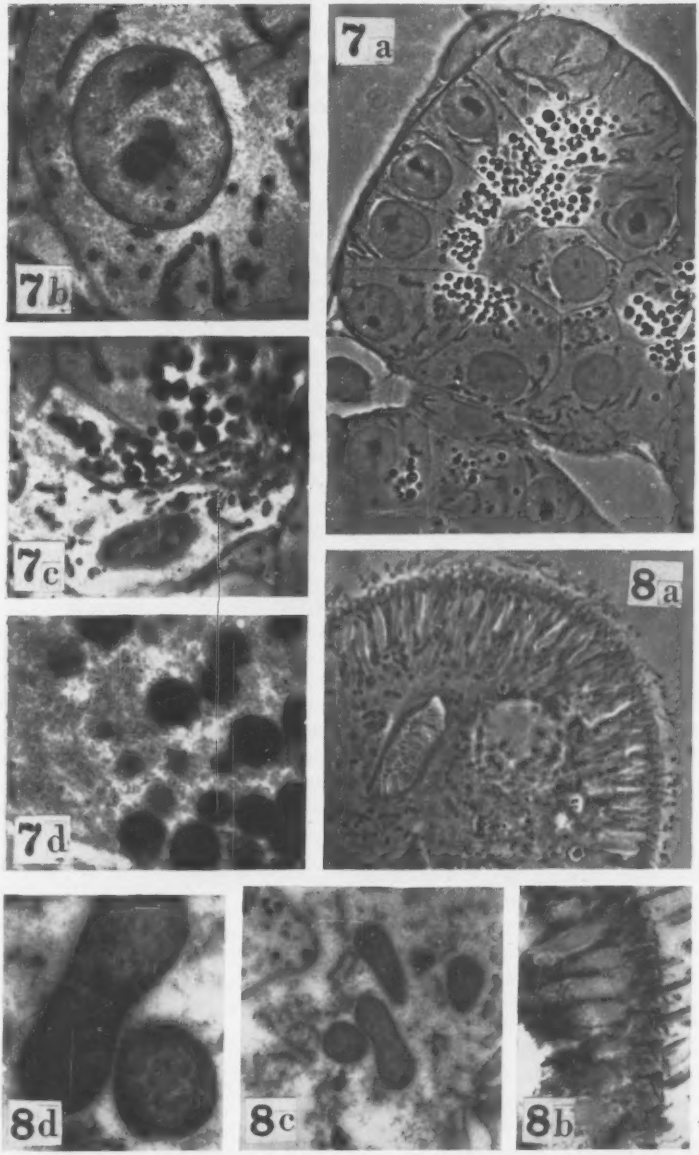

FIGURE 7.* Pancreas of a *Rana clamitans* tadpole. 7a. Phase contrast, 1,200 ×, 1 micron thick. 7b. Electron micrograph, 3,000 ×, 0.2 micron thick, showing nucleus and mitochondria of an acinar cell. 7c. Electron micrograph, 3,000 ×, 0.2 micron thick, showing zymogen granules of an acinar cell and the nucleus and cell body of a centro-acinar cell. 7d. Electron micrograph, 11,000 ×, 0.1 micron thick, showing zymogen granules of an acinar cell and the nucleus and cell body of a centro-acinar cell. 7d. Electron micrograph, 11,000 ×, 0.1 micron thick. Zymogen granules of an acinar cell. Note the fine structure of the surrounding hyaloplasm.

FIGURE 8. *Paramecium caudatum*. 8a. Phase contrast, 900 ×, 1 micron thick. 8b. Electron micrograph, 2,000 ×, 0.2 micron thick, showing subpellicular cytoplasm. Note mitochondria (dumbbell-shaped in longitudinal section) especially between trichocysts and at lower margin. 8c. Electron micrograph, 10,000 ×, 0.05 micron thick, showing mitochondria, macronuclear membrane, and cytoplasmic rodlets (microsomes). 8d. Electron micrograph, 22,000 ×, 0.05 micron thick. Mitochondria showing internal ultrastructure.

* Phase contrast and electron micrographs of the same sort of material as in FIGURES 1–6, to show the correspondence of density distribution in the two types of photographs.

the hyaloplasm, which we had come to associate with bad fixation, were apparent in the electron microscope, and less clearly in the phase microscope. By experimentation, a fixation has finally been achieved which in many tissue cells, preserves in the hyaloplasm (and within the larger cellular elements) an organized ultrastructure with the neatness or orderliness that characterizes the much grosser structure of the living cell in the light microscope (FIGURES 7d and 8d).

Very small pieces of tissue (with one dimension less than 2 mm.) are dissected rapidly from the live animal with a minimum of handling, and are fixed in 2 per cent OsO_4 which has been titrated to pH 7.4. After 15 to 30 minutes, the tissue is washed in three changes of distilled water (5 minutes each), then transferred to 2 per cent formaldehyde at pH 7.4 for 12 to 24 hours. It is then rapidly dehydrated and embedded in normal-butyl methacrylate according to the technique of Newman, Borysko, and Swerdlow.[3] For phase phase microscopy, one micron sections are cut and mounted on a glass slide. The methacrylate is removed with amyl acetate, and the sections are mounted in an oil of refractive index 1.460, under a cover-slip. FIGURES 1–6, 7a, and 8a illustrate the cytological quality of the resulting preparations. In general appearance and in details of nucleus, mitochondria, granules, hyaloplasm, *etc.* the cell morphology closely resembles that of living cells as described above. This entire procedure takes far less time and attention than standard fixing and staining, and these slides are as satisfactory for the study of cytoplasmic details as even the most successful stained preparations. The emancipation from staining jars and mordants should be welcomed by all students of cytoplasmic structure.

Even more important, perhaps, than the splendid cell morphology so easily revealed, is the fact that the phase visibility depends upon a physical property of the tissue itself, and not upon the still poorly understood consequences of chemical combination and physical adsorption. The structures are seen by virtue of the effective refractive index differences in the preparation which are a direct reflection of the differences in densities among the cell components. As a result, phase microscopy becomes a valuable adjunct to cytological electron microscopy, in which the contrast is also due to density differences in the specimen.*

Until recently it has been necessary to interpret cytological electron images of sectioned tissues by comparison with stained preparations. Such contrast depends upon factors very different from the density of the cell components, and as a result, the identification of structures in electron micrographs has often seemed questionable.

We make our preliminary study of a cell type with phase microscopy on one micron sections. Identical material cut at 0.05 to 0.2 micron is then placed in the electron microscope for detailed high resolution study. At all levels of electron magnification the structures can be identified readily; they are as familiar as the faces of old friends, thanks to the preliminary phase contrast study. This correspondence is shown in FIGURES 7 and 8. Furthermore it has become quite clear from such comparison that in this material, the electron beam rarely introduces morphological artifact above the 50 Ångstrom level of resolution.

In this brief treatment, an attempt has been made both to indicate the limitations of the phase microscope as applied to cytology, and to show a valuable use for the approach in connection with cytological electron microscopy. With thin sections, the phase contrast instrument can be made to show clearly all of the cell components which cytologists have been accustomed to study by artificial contrast, very often introduced by extremely difficult techniques. Phase contrast thus makes it possible to ignore the problem of stainability and concentrate upon fixation. A superior type of cytological fixation, which is also adequate

* The Lorenz-Lorentz law states,

$$d = \frac{n^2 - 1}{n^2 + 2}\frac{1}{r}$$

where

n = effective refractive index
d = density
r = specific refractivity

For the range n = 1.46 to 1.49,

$$\frac{n^2 - 1}{n^2 + 2}$$

can be roughly approximated by 0.19n. (Within this range are included most of the effective refractive indices of cell structures in OsO_4—formaldehyde fixed tissue mounted in Cargille's oil of n = 1.46.) This means that for constant r, the effective refractive indices of structures in such preparations are roughly proportional to their densities. Since for nucleic acids, proteins, and polysaccharides, as well as for our mounting medium, r falls in the range 0.26 to 0.28, in our phase microscope image, the optical densities are roughly proportional to the densities (*i.e.*, mass/volume) in the specimen.

When such preparations are studied with the electron microscope with an apertured objective, the optical densities in the image again are quite closely proportional to the specimen densities. Since, in our electron microscope preparations, the methacrylate is not removed from the section, and since it has about the same density as the oil in which the phase preparations are immersed; these two types of images may be said to translate, by diverse mechanisms, the same type of object differences into the same language.

for electron micrography is described. Phase microscopic study of one micron sections is recommended as preliminary to electron micrography of ultrathin sections (0.05 to 0.2 micron), since the relative optical density distributions of the two types of images can be made to match.

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A STUDY OF THE LIFE CYCLE OF SPIROCHETES AND OTHER MICRO-ORGANISMS BY MEANS OF PHASE CONTRAST AND ROUTINE MICROSCOPY*†

By EDWARD D. DELAMATER‡

By a careful selection of the recorded observations in the confused history of spirochete study, it is possible to select isolated observations (made by many different workers using various techniques) which indicate the probable occurrence of a complex life history or life cycle in this group of organisms. Because of their minute size and delicacy, and because of the difficulties encountered in staining them, there has been no acceptance of the interpretation of these results. In those instances where definite claims have been made concerning the occurrence of the complex life history, an acrimonious dispute has been usually precipitated.

The application of phase contrast microscopy by us to the study of spirochetes was accidental, but made it clear immediately that this old and confusing problem could be resolved by this means.

The problem was first approached with the cultivated non-pathogenic strains of *Treponema pallidum* (Kazan, Nichols and Reiter strains), and the observations were documented by means of photographs. The observations are essentially as follows:[1–6] Characteristic spiral, flexuous, and motile organisms were observed in profusion in young cultures. These reproduce actively by transverse division. As the age of the culture increases, minute granules, or gemmae, are produced at the sides of the organisms, and apparently are developed by the extrusion of a part of the spirochetal body into them. These at first may be very dense, but a single granule can be observed within many of them. A distinct membrane is differentiated at the periphery, and the granule lies attached to the one side of the membrane, the rest of the minute cyst being filled with a clear substance. Subsequently, a single spirochetal filament can be observed to develop from this granule. The adult spirochete is then liberated by literally kicking itself out through the membrane, although the membrane may remain attached to it for a long period. After its release from this unispirochetal cyst, the spirochete undergoes progressive transverse fission. It has been construed that transverse fission, which has been observed and followed on numerous occasions, constitutes one mechanism for vegetative reproduction. It has been further construed that the unispirochetal cyst just described, originating as a gemma, or lateral bud, constitutes a second method of vegetative reproduction.

More complex stages in the life cycle of spirochetes are also visualized by means of phase contrast microscopy. These consist of the formation of very dense lateral swellings, or swellings which develop within the continuity or body of a single spirochete, within which large numbers of granules are observed to develop and reduplicate by what appears to be a process of budding within the cyst. From each of these minute granules, individual spirochetes are observed to develop in essentially the same manner as that described for the unispirochetal cyst. These multispirochetal cysts may obtain tremendous size, measuring as much as 150–200 microns in diameter. When the spirochetes contained within them have reached adult dimensions, they are extruded from the cysts in tangled ropes or cords which subsequently separate into individual filaments, which in turn undergo successive transverse segmentation in the characteristic manner. Similar or identical multispirochetal cysts also appear to develop from union of two or more spirochetes.

Current, and as yet unpublished, observations on the times required for the development of the unispirochetal and multispirochetal cysts indicate that development proceeds over a matter of weeks

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and that once the process of cystic development is initiated it must proceed to its completion. The factors which induce or affect the production of these cystic forms are currently under investigation.

Once having observed the developmental stages in the saprophytic forms, the *T. pallidum* was studied as it occurs in experimental infected rabbit testes, and essentially the same sequence of events as described above was observed and documented. Further confirmation of these observations in the infected rabbit testis was made by means of specially developed staining procedures applied to smears of the infected testis. In these preparations essentially the same story could be perceived.

In more recent studies, *Borrelia anserina*, which produces blood spirochetosis in chickens, has been observed to undergo similar changes, both in the blood of the infected chick and in the chick embryo. Complete elaboration of this story in the infected chick, however, remains to be done.

It seems likely that the complex pattern of development, as observed in the five spirochetes studied to date, indicates that probably many additional spirochetes will eventually be shown to have comparable complex life cycles.

Following the application of phase contrast microscopy to the problem of life cycles in spirochetes, it was then possible to return to standard techniques with the routine microscope so as to observe comparable structures and interpret them. Further, it was possible to interpret electron photomicrographs in the existing literature on the basis of the phase contrast microscope studies.

Further application of this tool to the study of the nuclei of bacteria[9–13] showed the nuclear sites as areas of decreased density within which no structure could be made out; whereas by means of special and specific staining-dehydration procedures, nuclear and chromosomal structure and activity was delineated. By means of special minimal media and aging, the RNA of the cytoplasm, which has a density similar to that of chromosomes, was removed, and nuclear and chromosomal patterns similar to those observed in stained preparations could then be discerned.

The conclusion drawn here is two-fold; namely, that the phase contrast microscope constitutes a magnificent tool, and that its usefulness is greatly increased by using it in conjunction with other methods (a statement which confirms and extends the concept presented by Drs. Ornstein and Pollister).

Since this discussion of spirochetes represents an example of the application of phase contrast microscopy to biological problems, perhaps it would be justifiable to note some of the difficulties and limitations which affect its application. Since at least 80 per cent of the light applied to the condenser of the instrument is eliminated by the phase altering and condensing system, and is not available for either transmittal to the eye or the photographic plate, adequate flat and extremely intense light sources become of utmost importance. Since in problems such as these it ultimately becomes imperative to apply cinéphotomicrographic methods with limitations on exposure times, the problem of an adequate light source becomes of even greater importance. It is my impression that the single most important limiting factor in the application of phase contrast microscopy can be resolved into a solution of the problem of light. I would like to register the plea that Dr. Osterberg, and others who are currently investigating the physical aspects of the problem, apply themselves diligently to the production of adequate light. With the proper solution of the problems of adequate lighting, I can visualize innumerable biological problems which can be solved with facility.

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SECTION OF MATHEMATICS AND ENGINEERING

SOME BASIC PROBLEMS IN COMMUNICATION OF INFORMATION*

By L. A. ZADEH†

The effective use of geometrical methods by Shannon in his epoch-making Theory of Communication,[1,2] has served to pave the way for the introduction of function space techniques into communication theory. Heretofore, most of the work in this direction has centered around the geometry of multi-dimensional Euclidean spaces, although the use of more general types of spaces is implicit in Shannon's treatment of the generation of information by a source. Hilbert space representation of signals has been employed by Weston[3] in connection with the transmission of information through a channel; and various types of function spaces have been used by the writer in the study of linear signal transmission systems.[4,5]

It appears that communication theory offers a very fertile field for function space methods, perhaps even more fertile than that of quantum mechanics. In this paper we shall examine, in the light of function space concepts, some basic problems arising in connection with the communication of information, and thereby will obtain certain results that are not without practical significance.

Consider first the following problem: Let $X = \{x(t)\}$ be a set of signals. An arbitrarily selected member of this set, say $x(t)$, is transmitted through a noisy channel Γ and is received as $y(t)$. As a result of the noise and distortion introduced by Γ, the received signal $y(t)$ is, in general, quite different from $x(t)$. Nevertheless, under certain conditions it is possible to recover $x(t)$—or rather, a time-delayed replica of it—from the received signal $y(t)$. The case where the set $\{x(t)\}$ is an ensemble, *i.e.*, a set with a probability measure $P(x)$, is closely related to the process of ideal decoding in information theory. Here we are interested in the case where $\{x(t)\}$ is a set and not an ensemble. To put it another way, we are interested in a means of recovering $x(t)$ from $y(t)$ irrespective of the statistical characteristics of $\{x(t)\}$ and subject only to certain mild restrictions on the character of the noise introduced by Γ.

It will be convenient to use the symbolic notation

$$v = Nu \tag{1}$$

to indicate that a signal $v(t)$ is the response of a system N to an input signal $u(t)$. With this notation, the relation between $x(t)$ and $y(t)$ may be written compactly as

$$y = \Gamma x. \tag{2}$$

Correspondingly, the process of recovery of $x(t)$ from $y(t)$ may be represented by

$$x = \Gamma^{-1}y$$

where Γ^{-1} is the inverse of Γ, if it exists, over the set $\{y(t)\}$.

We represent the signals $x(t)$ and $y(t)$ as an ordered pair of points x, y in a signal space Σ, which is regarded as being imbedded in a function space with a delta-function basis. To each such pair of points we attach a distance function*

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* The notion of distance function was introduced by Frechet in 1906.[6]

$d(x, y)$, which serves as a measure of the disparity between $x(t)$ and $y(t)$. This function is assumed to possess the usual properties of a metric, except where it is expedient to omit the symmetry and triangle inequality requirements. The function $d(x, y)$ is similar to the function $\rho(x, y)$ used by Shannon in connection with the formulation of the rate of generation of information by a source.

The distance function $d(x, y)$ can have a variety of forms. Although we shall not be concerned with specific types of distance functions in this analysis, it will be helpful to have in mind a few that are of practical significance. Four such functions are listed below. [It is assumed throughout that $x(t)$ and $y(t)$ are defined over a long interval of time $(0, T)$. The letters l.u.b. stand, as usual, for "least upper bound of."]

(a) $$d(x, y) = \text{l.u.b.} \mid x(t) - y(t) \mid$$

This type of distance function is frequently used in engineering practice, although not in the context of the geometry of abstract spaces. When $x(t)$ and $y(t)$ are continuous signals, and the above $d(x, y)$ is used to define the distance between them, the signal space Σ becomes a Banach space.

(b) $$d(x, y) = \left\{\frac{1}{T}\int_0^T [x(t) - y(t)]^2\, dt\right\}^{\frac{1}{2}}.$$

This type of distance function has been, and still is, used predominantly in communication theory. When it is used in conjunction with square summable signals, the signal space Σ becomes a Hilbert space.

(c) $$d(x, y) = \text{l.u.b.}\left\{\frac{1}{T_0}\int_t^{t+T_0} [x(t) - y(t)]^2\, dt\right\}^{\frac{1}{2}}$$

where the braced quantity represents a moving time-average over an interval of length T_0 of the square of the difference between $x(t)$ and $y(t)$. By adjusting the parameter T_0, this distance function can be fitted to a variety of practical situations. It will be noted that (c) includes (a) and (b) as particular cases.

(d) $$d(x, y) = \frac{1}{T}\int_0^T \mid x(t) - y(t) \mid dt.$$

This type of distance function gives rise to L_1 space. It should be noted that, when applied to binary pulse sequences, the distance function in question becomes proportional to the number of binary digits in $x(t)$ which differ from the corresponding digits in $y(t)$, and vice-versa. In this form, the distance function (d) is used in connection with so-called self-correcting codes,[7] which are based essentially on the same principle as the reception process outlined below.

We are now in a position to examine a special but very inclusive case in which it is possible—under certain conditions to be discussed in the sequel—to achieve a perfect recovery of the transmitted signal from the received signal. Specifically, we consider the case where the set $X = \{x(t)\}$ consists of a finite number of discrete signals $x_1(t), x_2(t), \cdots, x_n(t)$, which play the roles of symbols or sequences of symbols. The replicas of all these signals are assumed to be available at the receiving end of the system.

Suppose that a transmitted signal x_k is received as y. To recover the transmitted signal from y,

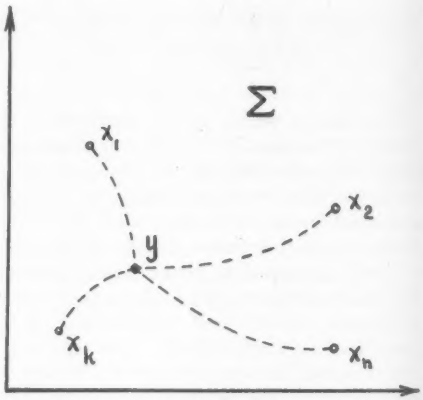

FIGURE 1. Recovery of the input signal by means of a comparison of the distances between the received signal y and all possible transmitted signals.

the receiver evaluates the "distance" between y and all possible transmitted signals $x_1, x_2, \cdots, x_n$ by the use of a suitable distance function $d(x, y)$, and then selects that signal which is "nearest" to y in terms of this distance function (FIGURE 1). In other words, the transmitted signal is taken to be the one that results in the smallest value of $d(x, y)$. This, in brief, is the basis of the reception process.

It will be noted that this principle is used in many of the conventional communication systems, although generally not in the quantitative terms formulated above. Rice, in particular, has employed a similar reception scheme in conjunction with a distance function of type (b) in his study of the probability of error for certain encoding schemes.[8]

The reception process under consideration allows one to recover the exact replica of the transmitted

signal on the condition that the received signal is always "nearer"—in terms of some distance function $d(x, y)$—to the actually transmitted signal than to any other possible signal. This condition may be expressed in a compact form

$$d(x_k, y) < d(x_i, y), \qquad i \neq k, \quad \text{for all } k \text{ and } i, \tag{3}$$

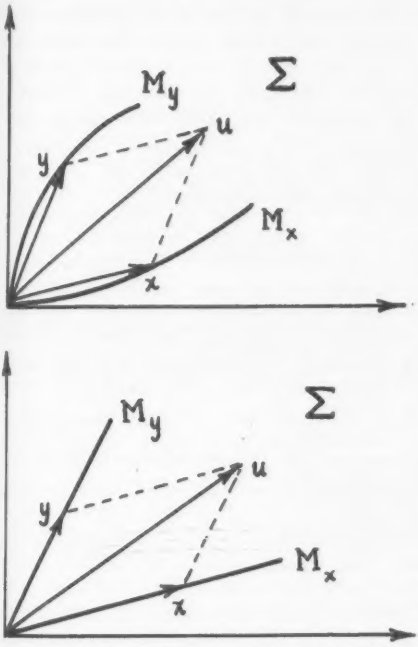

FIGURE 2. (a) Geometrical representation of nonlinear filtering. (b) Geometrical representation of linear filtering.

where x_k is the transmitted signal; y is the received signal; the x_i, $i = 1, 2, \cdots, n$, represent all possible transmitted signals; and $d(x, y)$ is a distance function. It is evident that condition (3) is fulfilled when the greatest lower bound of the distance between any two signals in X is greater than twice the least upper bound of the distance between the transmitted and received signals, provided $d(x, y)$ satisfies the triangle inequality.

A practical illustration of this process is furnished by the pulse code modulation (PCM) system. In this case, the set X consists of sequences of on-off pulses; the distance function is effectively of type (a); and the condition (3) is satisfied provided the least upper bound of noise amplitude is less than one half that of pulse amplitude.

In many practical situations it is inconvenient, or even impossible, to define a quantitative measure, such as a distance function, of the disparity between two signals. In such cases we may use instead the concept of neighborhood, which is basic to the theory of topological spaces. It appears that the theory of such spaces might find interesting applications in the realm of communication theory.

Next, we consider a somewhat different problem involving a multiplex transmission of two or more signals. For simplicity, we assume that the system has two channels. The sets of signals assigned to their respective channels are denoted by $X = \{x(t)\}$ and $Y = \{y(t)\}$. At the receiving end, one is given the sum signal $u(t) = x(t) + y(t)$, and is required to extract $x(t)$ and $y(t)$ from $u(t)$.

The problem is essentially to find two filters N_1 and N_2 such that, for any x in X and any y in Y,

$$N_1(x + y) = x \tag{4}$$

and

$$N_2(x + y) = y \tag{5}$$

irrespective of the probabilities of x and y. A filter such as N_1, which can extract any signal belonging to a set X from the sum of x and any signal y belonging to a set Y, is called an ideal filter.[9] The sets X and Y are referred to, respectively, as the transmission and rejection manifolds of the filter.

The mode of operation of an ideal filter may be formulated as follows. The signals $x(t)$ and $y(t)$ are defined over an interval $(0, T)$ and, over this interval, they are assumed to be representable as vectors x and y in an n-dimensional signal space Σ. To the two sets of signals X and Y there correspond two manifolds M_x and M_y in Σ. The manifold M_x is assumed to be characterized by k relations of the form

$$f_i(x_1, x_2, \cdots, x_n) = 0, \qquad i = 1, 2, \cdots, k, \tag{6}$$

where $x_1, x_2, \cdots, x_n$ are the coordinates of x, and the f_i are specified functions of these coordinates. Similarly, M_y is assumed to be characterized by l relations

$$g_j(y_1, y_2, \cdots, y_n) = 0, \quad j = 1, 2, \cdots, l, \tag{7}$$

where $y_1, y_2, \cdots, y_n$ are the coordinates of y, and the g_j are specified functions of these coordinates.

The knowledge of the sum of $x(t)$ and $y(t)$ results in another n relations between the coordinates of x, y, and u

$$x_\nu + y_\nu = u_\nu, \qquad \nu = 1, 2, \cdots, n, \tag{8}$$

where $u_2, u_2, \cdots, u_n$ are the coordinates of u, $u = x + y$.

The above relations add up to $k + l + n$ simultaneous equations in $2n$ unknowns $x_1, x_2, \cdots, x_n$ and $y_1, y_2, \cdots, y_n$. If $k + l = n$, these equations can, in general, be solved for the x_ν and y_ν by the use of machine computation or other means. Needless to say, the functions f_i and g_j should be such as to result in unique real values for the x_ν and y_ν.

When the above conditions are fulfilled, the solution of the system of equations 6, 7, and 8 yields the expressions for the coordinates of $x(t)$ in terms of those of $u(t)$ in the form

$$x_\nu = H_\nu(u_1, u_2, \cdots, u_n), \quad \nu = 1, 2, \cdots, n, \quad (9)$$

or symbolically

$$x = H(u) \quad (10)$$

The functions H_ν (or equivalently, their aggregate H) provide the desired characterization of the ideal filter in question.

It is seen that, in general, a filter such as N_1 may be regarded essentially as a computer which solves equations 6, 7, and 8 for the coordinates of $x(t)$ in terms of those of $u(t)$. Naturally, when these equations can be solved analytically and the resulting expressions for the H_ν are reasonably simple, N_1 may be synthesized in the form of a function generator which computes the x_ν from u_ν via H_ν. Such a situation occurs, for example, in the special but very important case where the equations 6 and 7 are linear. In this case the manifolds M_x and M_y are linear, and the operation performed by the ideal filter is essentially that of projecting the signal space Σ on M_x along M_y. The nonlinear and linear modes of ideal filtering are illustrated in FIGURES 2a and 2b in terms of two-dimensional signal space.

The fact that the sum of the dimensions of M_x and M_y must be equal to that of the signal space Σ [*i.e.*, $(n - k) + (n - l) = n$] is of considerable practical significance. In particular, it leads to the conclusion that, when linear modulation is employed, two sets of messages of bandwidth W require a channel of bandwidth $2W$, at the least, for simultaneous transmission.

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SECTION OF PSYCHOLOGY

MINORITY PERSONALITY AND ADJUSTMENT*

By GERHART SAENGER†

Minority personality and adjustment appears to be determined by a set of four interrelated factors. We need to consider, first, the ideology of the larger culture of which the minorities are part, as well as the possible existence of a separate minority ideology, which may be in conflict with that of the majority group. A second set of variables is provided by the extent of prejudice and discrimination. Population distributions and changing interrelations between majority and minorities play a role. Finally we have to take account of the direction of change toward an improvement or a deterioration of the relations.

The existence of a sound self-esteem which, in large measure, depends upon successful identification with one's own group is fundamental for the development of a well-adjusted personality. The feeling of being accepted, and accepting one's group, is basic for the individual's security. Where the group is considered inferior by the larger society, and membership in it related to deprivations, a positive identification with the group and the development of strong ties of belonging becomes difficult. Recent studies[1, 2] have shown that although Negro children identified themselves with their own group very early, after the age of five more than half showed a preference

* This paper was presented at the meeting of the Section of Psychology on February 18, 1952.
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for white rather than Negro physical characteristics. They rejected their own group and considered it inferior.

Such self-rejection often depends not so much on the prevalence of prejudicial beliefs in a society but rather on the acceptance of these beliefs by the minority group. In this country, for example, even Jewish college students shared the stereotyped notions concerning their group which were held by the rest of the college population.[3] Feelings of ambiguity about one's role, of inferiority, and of unworthiness result from the acceptance of these beliefs. Even where the minority group rejects the prejudicial opinions of the majority, we still need to consider the impact of avoidance, derision, ridicule, discrimination, and sometimes open attack usually encountered by the minority child roughly at the time when he enters school. When these negative experiences occur to children who reject majority prejudices, they are less likely to be harmful. Where the minority has accepted the prejudicial evaluation advanced by the majority, such traumata hit an already weakened ego. Much may depend also on the age of the minority child at the time when he is first exposed to the direct impact of prejudice and discrimination.

It appears that the rejection by the minority group of the belief in its inferiority is partially a function of the existence of positive group values; perhaps a separate language, religion, and culture, which are held to be worth preserving. The American Negro does not possess such separate culture, although the unassimilated Jew, and particularly European national minorities, have such indigenous culture.

A somewhat separate phenomenon which tends to bolster minority self-esteem is the rise of compensatory "racial pride," pointing to the accomplishments of outstanding minority members, athletes, scientists, and artists. Racial pride is probably enhanced by the existence of an indigenous culture. It is by no means clear whether such feelings could arise where there is no positive identification with the group. Its function in terms of building minority self-esteem is likely to be related to unconscious feelings of inferiority.

While the impact of prejudice and discrimination on the minorities is bound to lead to lowered self-esteem and insecurity, the pressure of discrimination itself tends to lead to compensatory developments which mitigate its effects. Among them we may cite the development of strong family ties among Jews, and the formation of closely knit, ghetto-like communities among immigrants in the United States, where the minority member feels protected and secure and obtains needed recognition.[5]

Another factor mitigating the impact of prejudice and discrimination on suppressed groups is the development of values which can be pursued within the framework of a discriminating society. The Jewish emphasis on book learning, which anchors prestige and self-esteem to activities not hampered by the restrictions of ghetto life, perhaps originates, at least partially, in the exigencies of the situation.[6]

The reaction to discrimination by the minority group is in all cases related to the values pursued by the society at large. In modern democratic capitalism, self-advancement becomes the major goal. It is part of the American dream that everyone is entitled to make the most of his abilities, and, in accordance with the belief in the equality of all men, is restrained only by the limits of his efforts and potentialities. The rejection of discrimination in this country, therefore, is determined to a considerable degree by the extent with which people are familiar with and believe in these principles. To generalize, discrimination will be rejected when: (a) the minority member accepts the values of the larger society and considers it his duty to advance himself; (b) believes that success should depend only on the individual's own merits; and (c) feels that he is not inferior to other groups.

A study of a cross-section of the New York City population showed that all ethnic groups believed to the same extent in the American dream and stated that success is mainly a function of individual endeavor.[7] In reality, as a result of the restrictions imposed by discrimination, Negroes have less opportunities than white Catholics and Jews, and white Catholics and Jews less opportunity than Protestants. In so far as the American dream holds true for the minorities to a lesser extent than for the majority group, the maintenance of their faith in it may psychologically be considered a failure to face reality.

Adjustment may be easier where minority members are not brought up to believe that they have a right to equal opportunity. Adjustment would still be easy where minority members have been taught that all people have the same right toward self-advancement within the limits of their abilities and potentialities, but consider themselves inferior individuals. The stronger the belief of

the minority in democratic ideals, and the more they tend to reject the belief in their own inferiority, the greater the amount of conflict engendered.

The reaction of minority groups to discrimination depends also on the extent and severity of discriminatory practices. Where discrimination is relatively light, we find a tendency toward increased attempts to overcome the additional obstacles resulting from minority status. Minority members may work harder, be more aggressive, and are more likely to protest. As the amount of discrimination rises, the likelihood of resignation and apathy increases and, ultimately, a lowering of aspirational levels occurs. An example of such adaptation to pressure can also be seen when the children of unemployed workers experience a lowering of ambitions and a narrowing of the range of phantasy in the realm of daydreams.[8] The lower aspiration level of groups such as the American Negro is, in all probability, due not only to the operation of such adaptive processes but also to isolation from the prevailing democratic ideology and successful people with high aspirations.

Minority people who accept discrimination, also consider protest as futile and serving only to aggravate their plight. They bolster their low self-esteem by a variety of means. Such persons tend to look down on other minorities and so feel superior to at least some people. Accepting majority prejudices, they prefer to identify with those who discriminate against them, and attempt to dissociate themselves from their own group. They believe that they resemble the majority members and that, if other members of their own group would behave as they do (like members of the majority), prejudice would disappear. Such identification with the oppressor has been observed even among concentration camp inmates.[9]

These defensive reactions result in a decline of the individual's sense of security, as well as a lowering of minority group solidarity and of feelings of communality of fate with other minority groups. Myrdal believed that the operation of these psychological mechanisms invalidates the Marxist theory that the suppressed groups would join together against their exploiters.

Finally, the self-esteem of the non-protesting minority member can be protected through an escape from reality and denial of the existence of discrimination through avoidance of contact with the majority.[10] Such escapist reaction is easier, however, where discrimination is limited and not openly practised.

Discrimination affects personality not only through interfering with processes of group identification and belonging; but more directly through majority demands that the minority display specific types of behavior, the effects of intimidation and fear, and the effects of objective deprivation. Negroes are rewarded for acting in a happy-go-lucky, humble, or servient manner.[11] In contrast, self-assured behavior, considered desirable for whites, is considered undesirable for the Negro and is often punished. Moreover, the emphasis on Negro dependency may well encourage infantile tendencies even in the absence of direct learning through reward and punishment. The required submission and self-abasement may produce a loss of respect, if not self-hatred, in the Negro. Adjustment here can be achieved through the adoption of masochistic traits: self-esteem restored by the feeling of having successfully fooled the white man by overtly acting in accordance with his demands, but secretly rebelling and laughing at him.[12]

The effects of fear and intimidation are an increased emotionality and anxiety, which are expressed in gestures, the voice, and furtive behavior.[13] Anxiety, together with deprivation and frustration of "rightful" expectations, often leads to increased aggression. To the extent that such aggression cannot be released directly for fear of reprisal, it will be displaced either toward one's own group, internalized, or expressed in the "projective systems" of mythology and religion.[14] The combination of overt resignation together with the rise of masochistic tendencies, as a means of handling aggression, has been said to lead to the rise of religious doctrines in which a reward for suffering is promised in the hereafter, when the oppressors (the rich) will be punished.[15] Revivalist forms of religion, in addition, provide an outlet for the pent-up emotions of the oppressed.

To the extent that discrimination keeps minorities in the lower class, it leads naturally to the adoption of lower class values and behavior.[16] Members of the lower-lower class in our society deviate from dominant middle class values by stressing cooperation rather than competition; they emphasize the pursuit of momentary pleasures rather than sacrifice in the interest of long range planning, and generally are more impulsive and less calculating. This behavior constellation may be considered a good adjustment to the uncertainties of their situation.[17]

Minority members can attempt to solve the problem of discrimination either by attempting to leave their group or by fighting discrimination. The path which is chosen depends in part on the reaction of society to the assimilation of different groups. American society encourages the assimilation of its white immigrant groups, but opposes the amalgamation of its racial minorities. This path depends also on the presence or absence of "racial pride" as well as the belief in indigenous group values worth preserving. Finally, it depends on the actual strength of the discriminatory barriers, or the chance that attempts to leave the group will succeed.[18] The drive to leave the group will increase as the chances for success become greater, or as the goal is more nearly approached.

Nevertheless, attempts to leave the minority lead to alienation from the group in which the individual grew up. The successfully mobile person is rooted neither in the lower status group, which he leaves behind and more or less rejects, nor in his new group, in which he is not yet fully accepted. He leaves behind the less-assimilated members of his old group, including his parents, a process often accompanied by feelings of shame and guilt.

The very process of assimilation of a minority group as a whole tends to affect the psychological situation of its members. Within the ghetto, it is not the individual so much as the group who faces attack from the outside. The communality of the attack preserves the cohesiveness of the group. Where assimilation leads to a dispersion of the group, the individual who now finds himself living in isolation in a more or less unfriendly world, is under attack without the protection of group support. Contact with majority members, particularly when the individual rejects his own group, leads to heightened self-consciousness. In his attempts to conceal those traits which in his opinion stigmatize him as a minority member, the individual watches his behavior for signs betraying his minority origin and, often at the same time, hates himself for doing so. He may feel under observation and hence unable to be spontaneous and introspective.[20]

Adjustment is easier where the minority attempts to fight prejudice and discrimination, and where the members accept their group and identify with it. Protest against discrimination enhances one's ego, and makes the members of the group more secure. In this connection we also have to consider the perceived strength of the ingroup as well as the direction of change in majority-minority relations. It is not the absolute level of interrelations but the relative level which determines how the situation is viewed. Where conditions are improving, minority members may feel optimistic, whereas where conditions are deteriorating, pessimistic if not desperate.

While little is known about the effect of changes in intergroup relations, it appears conceivable that where there is an initially positive identification with a group engaged in fighting discrimination, an improvement may lead to greater group cohesiveness. On the other hand, an improvement in intergroup relations, by counteracting trends which lead to personality differences, may contribute to the final assimilation of the group. Merton[21] in his theory of the self-fulfilling prophecy, indicates how the deviant personality characteristics of the minorities are in themselves the consequences of prejudicial beliefs and resulting discriminatory actions. The belief that minority members are aggressive leads to majority hostility creating aggressive reactions in the minority. The belief that members of a given race are lazy and unintelligent leads to a restriction of job and educational opportunities, which in turn create lower aspirations and performance levels. To the extent that the process is reversible, one may theorize that the lowering of discriminatory barriers will contribute to the disappearance of minority characteristics, and, particularly where the minority does not possess a culture of its own, lead to the ultimate disintegration if not disappearance of the group. This process is facilitated by the fact that an improvement in ethnic relations brings with it increased group contact which speeds up assimilation, particularly where participation in the more highly-valued majority culture brings with it material and social advantages.

A deterioration in intergroup relations may be followed by a decline in group morale, which usually contributes to group disintegration, counteracted here by the need for mutual support. To the extent that a decrease in minority status may lead to lowered self-esteem and fear, but may be compensated for by increased group cohesion and feelings of belonging and perhaps the development of "racial pride," the ultimate effect is difficult to assess.

In the face of the handicaps of minority membership, it might be interesting to speculate why adjustment differences between majority and minority members are not greater than they appear.

We noted the appearance of compensatory mechanisms facilitating the adjustment of the minority group to its situation. But we must not forget that prejudice and discrimination contribute also to the maladjustment of the majority group.

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SECTION OF ANTHROPOLOGY

ON THE ZOOLOGICAL POSITION AND THE EVOLUTIONARY SIGNIFICANCE OF AUSTRALOPITHECINES*

By PIERRE TEILHARD DE CHARDIN†

During a recent trip to South Africa‡ I was able, with the help of my colleagues there, to estimate at first hand the importance to science of the Australopithecines, as compared with the Far Eastern Pithecanthropines. I should like to take this opportunity to report on certain points which seem to me most significant in connection with their group.

1. *The Zoological Importance of the Australopithecines.* Before the last investigations made by Broom, Dart and Robinson, we were still able to believe that the Australopithecines were nothing more than a rare zoological curiosity. Now, however, it has become clear that they represent an important population, once widely disseminated over a large portion of South Africa. From Taungs (in the Kimberley area) to Makapan (North of Pretoria), passing through the Sterkfontein region (near Johannesburg), the Australopithecines-bearing breccias extend for about 350 miles from south to north. Furthermore, everything leads us to believe that they will soon be discovered in Angola, to the west, as well as much further north across Rhodesia and into Tanganyika, where two upper premolars have been found. Dr. A. Remane has recently referred these to the genus *Meganthropus* of Java but, in my opinion, they should rather be classed with the Australopithecines than with the Pithecanthropines.

2. *The Morphological Autonomy of the Australopithecines.* Even if we take into account their high individual variability and their strong sexual dimorphism, the Australopithecines seem to have been an extremely polymorphous group. And yet they share a common, easily recognizable, fundamental pattern, proving that in their case (just as with the Pithecanthropines) we are dealing not with a composite collection of forms, but with a single natural group, caught in a phase of rapid evolution.

* This paper, illustrated with lantern slides, was presented at the meeting of the Section of Anthropology on February 25, 1952.

† Academy of Sciences, Paris, France.

‡ A journey sponsored by the Wenner-Gren Foundation of New York.

Essentially this common pattern, readily recognizable by the palaeontologist, consists of the following characteristics: crowns of molars very broad and complicated (distinctly more so than in Man); lower anterior premolar non sectorial,

Apes known so far, and they are strongly hominoid ("hominoid" however does not mean "human"). In no case, until now, neither in their brain capacity, nor by the reduction of their face, nor by any association of their bones with any trace of fire or

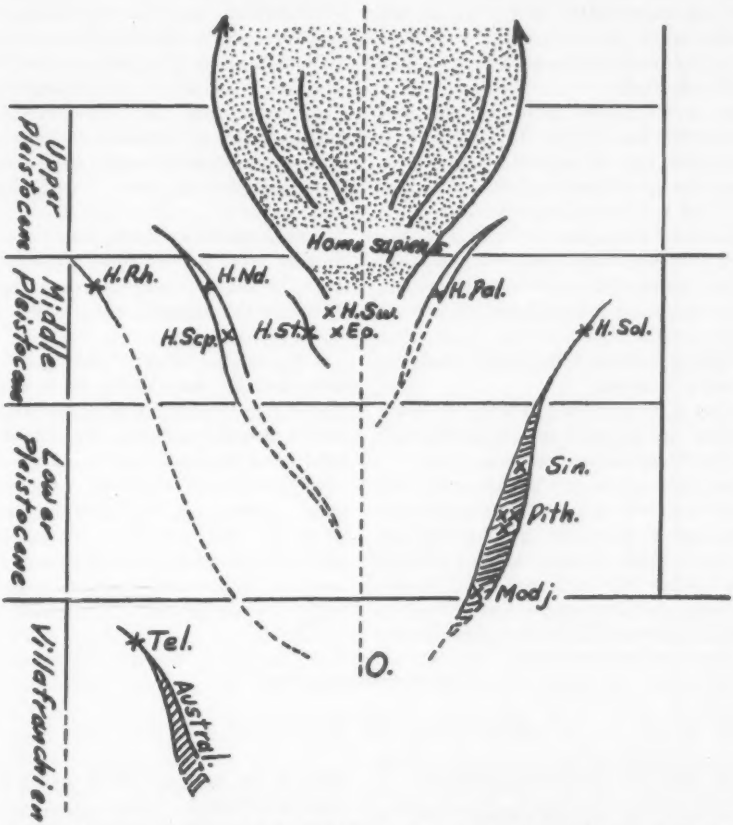


FIGURE 1. Hypothetical structure of the human phylum, as suggested by the Australopithecines and the Pithecanthropines. Key: *H.Rh.*, Rhodesian Man; *H.Nd.*, Neanderthal Man; *H.St.*, Steinheim Man; *H.Sw.*, Swanscombe Man; *H.Pal.*, Palestine Men; *H.Sc.*, Saccopastore Man; *Eo.*, *Eoanthropus*; *H.Sol.*, Solo Man; *Sin.*, *Sinanthropus*; *Pith.*, *Pithecanthropus* group (and *Meganthropus*); *Modj.*, Modjokerto Man; *Tel.*, *Telanthropus*; *Austral.*, Australopithecines. *O* is the presumed point of human origin. In *H. sapiens*, the originally diverging elements composing the human phylum are decidedly converging under the pressure of forces of socialization.

molarized; small canines and incisors; markedly straight mandibular symphysis; shape of the pelvis indicating, in all cases (*e.g.*, *Australopithecus*, *Plesianthropus*, *Paranthropus*), an erect posture.

Due to these various osteological features,* the Australopithecines differ from all living and fossil

* And also because of the high degree of instinctivity which such a defenseless animal must have possessed in order not only to survive, but to thrive, in a highly competitive environment.

any true implements can the Australopithecines (in contrast to the Pithecanthropines) be considered as a zoological group which, at any time, crossed the divide between Ape and Man. But they seem to form an autonomous group which, to some extent, bridges the two.

3. *The Geological Age of the Australopithecines.* In Africa, as is well known, the conservative nature of the fauna and the absence of major Villafran-

chian tectonic movements make the definition of a limit between the Tertiary and the Quaternary particularly difficult. On the other hand no indisputable sequence has yet been recognised either in the deposits or in the fauna of the Australopithecines-bearing fissures.

Under these circumstances, all that we can definitely affirm at this time, with regard to the geologic age of the Australopithecines, can be reduced to the following points:

a. The mammalian fauna found associated with the Australopithecines, in spite of its high content of extinct types, does not appear to differ essentially from the remarkably archaic fauna associated with the first human industries, both in the stratified series of Kenya and in the Vaal gravels.

b. Until now, in the fossiliferous fissures of South Africa, the Australopithecines-bearing breccias and the human industry-bearing deposits have been mutually exclusive. So far, the two types of formations have never been found unequivocally associated in the same site.

c. No breccia has yet been identified in South Africa which can be attributed to a third and older system of fossiliferous fissures.

All these facts are in perfect agreement with one another if we look upon the Australopithecines as a widely spread group of large, especially progressive Apes, which was in possession of South Africa just before Man appeared in his turn to displace and replace them on their own ground.

4. *The Significance of the Australopithecines with Regard to the Origin and Structure of the Human Group.* From the preceding observations, it becomes evident that as a result of their combined infra-human and para-human characteristics, the Australopithecines cannot be considered the direct ancestors of Man.

Nevertheless, in so far as the initial position and composition of the human phylum is concerned, a study of their group supplies us with important data from three different lines of approach.

a. *Systematically.* As I observed above, the Australopithecines represent a zoological type of a remarkably intercalary nature, which almost brings Man and Ape to the point of morphological contact.

b. *Geographically.* Their late-tertiary (?) occurrence in Africa (the main center of Primates evolution) offers an additional argument for the thesis that this continent was the main birthplace for the human group.

c. *Phyletically.* The curiously symmetrical position held by their branch (as compared with that of the Pithecanthropines, FIGURE 1) in relation to the presumed point of human origin, confirms in us the idea that the human group exhibited, originally, the same ramified structure which palaeontology is gradually detecting in every large animal phylum. All this, despite the fact that this complexity and divergency (due to action of Speciation) is obscured today in *Homo sapiens* by the great converging forces of Socialization.

*DIVISION OF MYCOLOGY**

A SURVEY OF THE MUCORALES†

By C. W. HESSELTINE‡

The Mucorales are a group of fungi in the higher Phycomycetes which are characterized by the formation of non-motile, asexual spores (sporangiospores) within a spore case (sporangium). The sexual state is marked by the fusion of two gametangia with the production of a sexual spore (zygospore). The vegetative mycelium is typically in the substrate and is said to be without septa (coenocytic).

Man's knowledge of the order dates back to the middle of the 17th century, when Robert Hooke described a black mold which may well have been the black bread mold, *Rhizopus nigricans*. A few years later, John Ray (1688) described what is definitely known to be a member of the Mucorales, namely Pilobolus. Linnaeus, in his "Species Plantarum," included *Mucor* as one of the ten fungi which he recognized. Tode, in 1790, created the genus *Pilobolus*. Fries, with whom the starting date for the nomenclature of the order begins, made the serious error of placing the then-known members of this order with the puff balls (Gastero-

* A paper entitled "Problems in the Taxonomy of the Actinomycetes" was presented by Selman A. Waksman at the meeting of the Division of Mycology on February 29, 1952. No abstract of this paper has been received.

† This paper, illustrated with lantern slides, was presented at the meeting of the Division, February 29, 1952.

‡ Lederle Laboratories, Pearl River, New York.

mycetes). Later, in the third volume of his "Systema Mycologicum," he recognized this error and placed them in the Hyphomycetes. The first American investigator was De Schweinitz (1834), who described sixteen species of *Mucor* and one species of *Thamnidium*.

In spite of the early extensive publications on this group, it was not until 1873 that a clear understanding of the order emerged. In the 1870's, van Tieghem published three papers, one in collaboration with Le Monnier, which defined the family Mucoraceae and erected several genera which exist today. He also distinguished four tribes under the family, which today have been raised to family rank. This work was characterized by adequate descriptions of the species which were studied. Not only were the descriptions complete, but definite spore measurements were given, and each species fully illustrated. These three papers actually mark the beginning of a taxonomic understanding of the group. Van Tieghem also employed crude culture techniques which enabled him to study more effectively the growth of these fungi. Brefeld, who had first initiated culture work, gave us some beautiful illustrations of the order, and the subclass name Zygomycetes. His descriptions and determinations, however, leave much to be desired.

Of the modern taxonomic works on the Mucorales, one must turn to Fischer (1892), Lendner (1908), Zycha (1935), and Naumov (1939). Blakeslee (1904) made the very interesting and important discovery that most members of this order were heterothallic; that is, only zygospores were produced when opposite mating types were placed together. In less frequent cases, he found that a homothallic condition existed in which zygospores were produced from the mycelium derived from a single asexual spore. Buller in his "Researches on Fungi" beautifully illustrated the spore discharge mechanism of *Pilobolus* and its response to light.

The origin of the Mucorales is as yet somewhat in doubt. Most students of the order believe that their ancestors are to be found in the Saprolegniales (water molds) or in the Lagenidiales and Chytridiales. From the viewpoint of asexual reproduction, there is a striking similarity of the Mucorales with the Saprolegniales. A great many forms in both orders occur regularly in soil, although some of the members of the Saprolegniales are aquatic. Each possesses stout mycelium, which becomes quite extensive. This produces sporangia containing motile cells in the water molds, while in the mucors non-motile spores always occur. In certain genera of the Saprolegniales, such as *Aplanes*, the products of the sporangium encyst at the opening of the sporangium and fail to produce zoospores, germinating instead with germ tubes as in all the Mucorales. Both groups show the production of thick-walled resting cells in the old mycelium.

The similarities in the sexual reproduction between the Saprolegniales and the Mucorales are also marked. In both orders, homothallic and heterothallic forms occur. In each, the spore formed as a result of gametic union (oospore and zygospore) functions as a resting cell, and each may germinate to give rise to a sporangium or to vegetative mycelium. Although it is true that in many members of the Saprolegniales there are two or more oospores formed in an oogonium, in some only a single product of gametic union is present. Parthenogenetic spores are known to occur in each group.

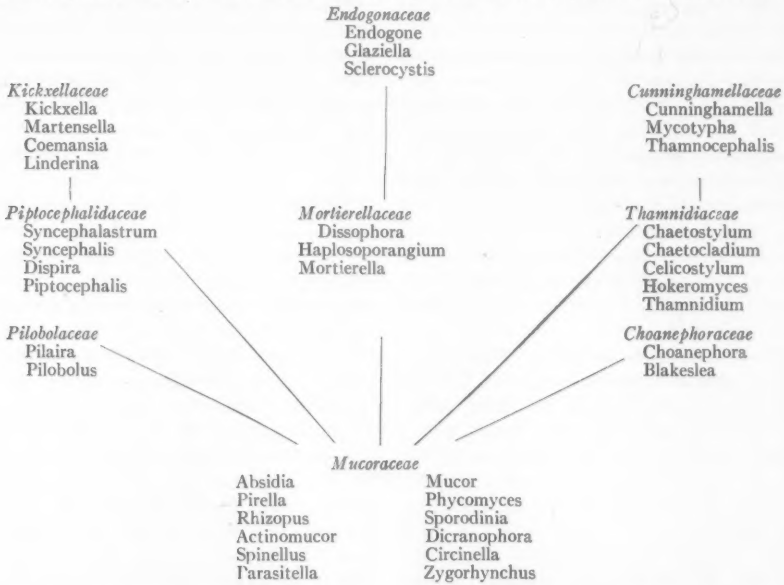
The principal objection to the relationship of the Mucorales to the Saprolegniales is in the fact that the oospore lies within the oogonium wall, whereas the wall of the zygospore is the result of the combined walls of the two gametangia. In the Saprolegniales the gametangia are unequal in size, although unequal gametangia occur in such genera as *Zygorhynchus*. Actually, in some species where the gametangia are equal in size, the nuclei and part of the cytoplasm of one pass into the other so that for all practical purposes we have a condition comparable to that found in the water molds. In Dicranophora the gametangia are very unequal in size, and apparently the contents of the male element migrate directly into that of the female with the zygospore wall composed almost entirely from the female gametangium. Thus we have a condition which is almost identical with that present in the Saprolegniales. A second criticism might be the difference in the chemical nature of the cell wall. It is said to be cellulose in the water molds and chitinous in the mucors. There are conflicting reports, however, as to whether cellulose is absent or present in the Mucorales. Further study is needed to clarify this point.

The implications of the existing evidence seem to indicate that the order is represented by nine fairly sharply defined families, each containing two or more genera. A tentative scheme of their re-

lationships and members is shown in TABLE 1. It must be emphasized, however, that these represent only a system based upon the present evidence, most of which is derived from asexual development and morphology, and the formation of zygospores and their external appearance. In addition, some of the conclusions are further substantiated by physiological and ecological similarities, such as are found in the Pilobolaceae, where all species are strictly coprophilous. So far, the comparative cytological evidence is too incomplete to be of any value in determining family relationships.

TABLE I

SUGGESTED ARRANGEMENT AND RELATIONSHIPS OF THE GENERA AND FAMILIES OF THE MUCORALES



The largest and most primitive family seems to be the Mucoraceae. In the genus *Mucor*, which can be used as the type of the family, asexual reproduction occurs by the formation of sphaerical sporangia containing many spores. Each sporangium possesses a thin sporangial wall and contains a large columella. The zygospores are produced between equal, straight suspensors which are not marked by any outgrowths. The wall of the zygospore is thickened and marked by long prominent projections. This genus *Mucor* contains many species which occur in soil, on dung, on seeds, *etc.* With certain minor modifications, all the other genera in the family possess these characters. The most conspicuous of these are the outgrowths arising from the suspensors in such genera as *Phycomyces* and in some species of *Absidia*.

One of the families most closely related to the Mucoraceae is the Pilobolaceae which contains but two genera, both of which are dung inhabiting. The sporangial wall in this family is of a chitinous nature which holds the spores in place, instead of allowing ready dissemination as in the Mucoraceae. In *Pilobolus* a swelling occurs beneath the sporangium which brings about its explosive discharge. The most striking feature of the Pilobolaceae, however, is the nature of the zygospore. Reported cases of zygospore formation indicate that the two gametangia lie parallel to each other or are even coiled about each other. This is somewhat similar to the tongs-shaped suspensors seen in *Phycomyces*, to which *Pilaira* and *Pilobolus* are most closely related. However, they differ from *Phycomyces* by the absence of projections upon the suspensors. In addition to these characters the zygospores are smooth-walled. Although *Pilaira*, like all the Mucoraceae, can be readily grown on ordinary culture media, *Pilobolus* apparently has become so specialized in its requirements that it will grow only upon dung agar.

A second line of evolution seems to have been followed in the Piptocephalidaceae in which both the sporangium and the zygospore have been greatly modified. Instead of the sporangium being spherical, there has been a reduction in the number of sporangiospores and a concentration of many sporangia (mero-sporangia) upon a swollen vesicle. Each sporangium has lost its columella and forms its spores in a linear fashion. *Syncephalastrum* appears to be the basic genus, since it has a simple nutrition and grows as a saprophyte. In the genera *Dispira*, *Syncephalis*, and *Piptocephalis* the saprophytic existence has been lost in favor of a parasitic life on other Mucorales. The zygospores are formed between tongs-like suspensors.

The Kickxellaceae appear to be related to the last mentioned family by further sporangial reduction. In this family the merosporangia apparently are reduced to single spores (conidia). The conidia are borne upon sterigmata which in turn are produced from sporocladia. The conidium in *Kickxella* possesses a pseudoseptum, which may be evidence that this is a reduction of a two-spored sporangium to a single-spored one. The single case in which zygospores have been seen indicates essentially the same type as those of the Piptocephalidaceae. Some members of the family are parasitic while others are not.

Choanephora and *Blakeslea* represent a closely related assemblage of species usually occurring as weak parasites on flowering plants. The asexual state is represented by the usual *Mucor* sporangium but, in addition, all members produce (on separate stalks from the sporangiophores) either small sporangia containing a few spores (sporangiola) or conidia—never both conidia and sporangiola in a single species. Both conidia and sporangiola are borne upon enlarged vesicles at the top of the stalk. Apparently, sporangiola have been reduced to conidia in certain forms. The zygospores which are formed in a manner similar to those in *Pilobolus* are smooth-walled. The resemblance of the colony appearance and the short viability of cultures all point to a very close relationship between the two genera.

A fourth line of evolution appears to be represented by the families Thamnidiaceae and Cunninghamellaceae. In all the cases known, the zygospores are similar to those of *Mucor*. The nutritional requirements are simple and all forms seem to lead a saprophytic life. However, they have evolved strikingly along the line of reduction of the *Mucor*-type sporangium to that of conidia. In the Thamnidiaceae there is a transition from the genus *Thamnidium*, in which the sporangiophore is terminated by a *Mucor*-like sporangium with sporangiola borne on branches of the same sporangiophore, to one-spored sporangia. In *Helicostylum* and *Chaetostylum* there has been a reduction in the terminal sporangium which may be replaced by a spine, or the branches bearing the sporangiola may in some cases end in spines. A further reduction occurs in *Chaetocladium*, in which no sporangia are ever produced and the sporangiola are all single spores with the ultimate branches ending in sterile spines. Each conidium can be readily separated from its sporangial wall. In the Cunninghamellaceae only conidia are found which instead of being borne as sporangiola, are borne in large numbers upon swollen vesicles. The sporangial wall surrounding the spore can not be demonstrated.

In the eighth family, Mortierellaceae, sporangia are formed as in *Mucor*, but there is little or no columella formed. The number of sporangiospores are smaller and are reduced to two or one in the genus *Haplosporangium*. Where zygospores are present, however, the zygospore is formed between tongs-like suspensors. An additional feature hitherto not seen is the growth of hyphae about the zygospore so that it is surrounded and covered by hyphal filaments. Although the sporangium lacking a columella is considered to be a primitive character, its reduction to one-spored conidia, and the smooth-walled zygospores enclosed by mycelium, all indicate an advanced condition.

The last family, Endogonaceae, is of a very uncertain position since it has been little studied. Most recent investigators place it in the Mucorales as one of the forms most advanced in development. The members of this family, like those of the Mortierellaceae, are saprophytic and have the same general vegetative growth. In certain cases sporangia are formed which are similar to those in *Mortierella*. However, the sporangia, chlamydospores, and zygospores are each produced inside a mycelial covering (sporocarp). The zygospores resemble those of *Piptocephalis* in which the zygospores are borne above the two gametangia. Actually these forms may represent a collection of very diverse organisms which are not closely related to each other.

Thus we have a fairly coherent collection of families and genera which have evolved from the basic *Mucor* type. In the future additional forms may be found which are known today, but in which the zygospore is at present unknown. It is also possible that a few of the genera listed above, where zygospores have not been demonstrated, may have to be removed when the perfect stage is discovered. A detailed citation of the literature may be found in the references given below.

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CONFERENCES HELD

SECTION OF PSYCHOLOGY

"COMPARATIVE CONDITIONED NEUROSES IN HUMAN AND OTHER ANIMALS"

FEBRUARY 22 AND 23, 1952

The Section of Psychology held a Conference on "Comparative Conditioned Neuroses in Human and Other Animals." Doctor Edward J. Kempf, Wading River, Long Island, New York was the Conference Chairman in charge of the meeting.

The program consisted of the following papers:

Friday, February 22

Morning Session. Chairman: Edward J. Kempf.

"Review of History of Experimental Production of Neuroses in Dogs," W. Horsley Gantt, Pavlovian Laboratory, Johns Hopkins Medical School, Baltimore, Md.

"A Comparative Approach to the Dynamics of Conditioning Neuroses," Howard S. Liddell, Cornell University, Ithaca, N. Y.

"Morphological, Constitutional and Dominance-Submission Factors in Conditioning," William T. James, University of Georgia, Athens, Ga.

"Neuro-Endocrine Components of the Physiological Response to Stress," B. F. Graham, Allan Memorial Institute, Montreal, Quebec, Canada.

Discussants: Hudson Hoagland, Worcester Foundation for Experimental Biology, Shrewsbury, Mass.

N. Raschevsky, University of Chicago, Chicago, Ill.

Afternoon Session. Chairman: W. Horsley Gantt.

"Factors Modifying Conditioned Reactions and Their Relations to the Autonomic Nervous System," Ernst Gellhorn, University of Minnesota Medical School, Minneapolis, Minn.

"Cross Sectional and Longitudinal Studies of Adjustive Behavior in the Dog," John L. Fuller, Roscoe B. Jackson Memorial Laboratory, Bar Harbor, Me.

"Experimental Induction of Disturbances in Appetitive Selection," Curt P. Richter, Henry Phipps Psychiatric Clinic, Johns Hopkins Medical School, Baltimore, Md.

"Sexual Neuroses in Animals," George Mahl, Yale University, New Haven, Conn.

Discussants: W. N. Kellogg, The Florida State University, Tallahassee, Fla.

Frank A. Beach, Yale University, New Haven, Conn.

Saturday, February 23

Morning Session. Chairman: Edward J. Kempf.

"Animal and Human Neuroses," Jules H. Massermann, Northwestern University, Chicago, Ill.

"Human Conditioning and Anxiety," L. Welch, Hunter College and Cornell Medical College, New York, N. Y.

"Neurosis: A Disorder of Conditioning or of Problem Solving?" O. H. Mowrer, University of Illinois, Urbana, Ill.

"Relation of Cerebral to Autonomic Activity in Conditioned Emotional Reactions of Children," Chester W. Darrow, Institute for Juvenile Research, Chicago, Ill.

Discussants: Joseph Wortis, New York University, New York, N. Y.

David McK. Rioch, Walter Reed Army Medical Center, Washington, D. C.

Afternoon Session. Chairman: Howard S. Liddell.

"Neuroses as Conditioned Conflicting, Holistic Attitudinal Acquisitive and Avoidant Reactions," Edward J. Kempf, Wading River, Long Island, N. Y.

"Relation of Life Situations to Emotional Reactions and Gastro-Intestinal Functioning," Harold G. Wolff, Cornell University Medical College, New York, N. Y.

"Human Emotional Cardio-Vascular and Respiratory Conditioning," William G. Reese, University of Arkansas, Little Rock, Ark.

"Conditioned Compulsive Behavior in Schizophrenia," Stephen Fleck, University of Washington, Seattle, Wash.

Discussants: George F. Sutherland, Duke University, Durham, N. C.

John C. Whitehorn, Johns Hopkins Medical School, Baltimore, Md.

The Section of Psychology provides conferences for active workers in the special fields of Psychology.

Attendance is limited to those invited to participate in these conferences and to interested Members of the Academy.

NEW MEMBERS

Elected February 28, 1952

SUSTAINING MEMBERSHIP

Kuder, Katherine, M.D., Obstetrics & Gynecology. Medical Director, Ortho Pharmaceutical Corp., Raritan, N. J.

Randall, Henry T., D.Sc., Surgery. Clinical Director, Memorial Hosp., New York, N. Y.

ACTIVE MEMBERSHIP

Adams, Joseph John, M.S., M.E., Mechanical Engineering, Biochemistry. Senior Test Engineer, Paterson, N. J.

Adelsberger, Lucie, M.D., Immunology, Cancer Research. Research Assistant, Lab., Div., Montefiore Hosp., New York, N. Y.

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Ang, Eriberto L., M.D., Diseases of the Chest. Chief Resident Physician, Div. II, B. S. Pollak Hosp. for Chest Diseases, Jersey City, N. J.

Arnold, Godfrey Edward, M.D., Otolaryngology. Clinical Assistant, Dept. of Otolaryngology, Bellevue Hosp., New York, N. Y.

Arrowood, Julia G., M.D., Anesthesiology. Chief of Anesthesia Service, Mass. Mem. Hosps., Boston, Mass.

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Bakay, Louis, M.D., Neurosurgery. Assistant in Surgery, Harvard Med. School, Mass. Genl. Hosp., Boston, Mass.

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Bevilacqua, Sylvio, Pathology, Biology, Biochemistry. Assistant Prof., Dept. of Pathology, Faculdade Nacional de Odontologia, Univ. of Brazil, Rio de Janeiro, Brazil.

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